Prince George Forest Region

Forest Resources & Practices Team

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Note # PG-01

FOREST RESEARCH NOTE

Testing Silvicultural Systems for the ESSF
Early Results of the Lucille Mountain Project

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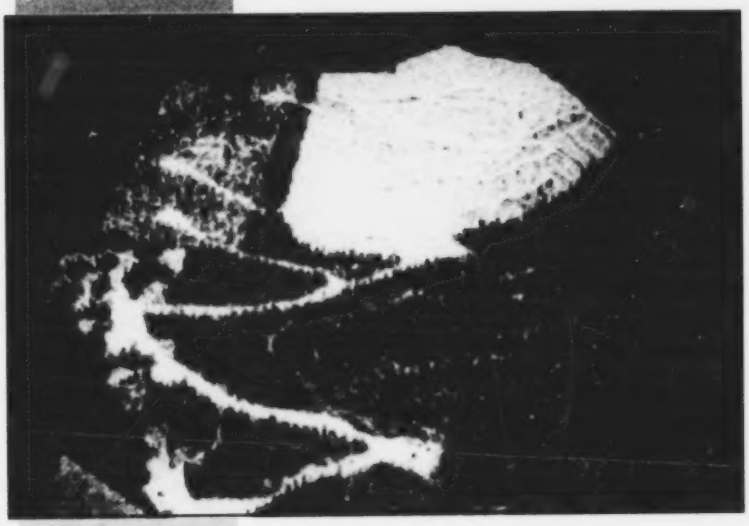
Introduction and Background

The Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic zone is one of the most extensive forest zones in British Columbia, covering 13.3 million hectares or 14% of BC's land area. It is also one of the province's most severe climates for forest growth. In much of the central interior, the ESSF zone is a large component of the forest land base. For example, the ESSF zone makes up 45% of the net productive forest land base in the Robson Valley Forest District and approximately 15 to 20% of the Prince George and Dawson Creek Districts.



Aerial view of the Lucille Mountain ESSF silvicultural systems trial

ESSF forests are important for wildlife and biodiversity. They influence snow melt and water flow in most mountain watersheds and they have high recreation and aesthetic values. These forests are also considered an important part of the projected timber supply in the Prince George Forest Region.

Traditionally, ESSF sites have been harvested, planted and managed under even-aged clearcut silvicultural systems. Clearcutting offers some operational and economic advantages for short-term harvesting and silvicultural operations. The cost of road access in difficult terrain is lower in clearcut operations, compared to partial cutting. By removing forest cover, clearcutting helps "warm the soil" for planted seedlings and makes slash disposal easier, facilitating planter access and pest management.

However, experience with clearcut systems in the ESSF zone indicates that reforestation is often slow and can be difficult due to the short growing seasons and harsh climate associated with this subalpine region. And, extensive clearcutting in the ESSF zone is increasingly in conflict with other forest values such as visual quality and wildlife habitat, especially mountain caribou habitat.

It is often suggested that retaining some mature forest cover after timber harvesting through partial-cut silvicultural systems may address both the biological and the integrated resource management (IRM) issues associated with forest management in the ESSF. However, there is little reliable scientific data available to help assess the relative ecological advantages and disadvantages of clearcutting and partial-cutting in ESSF forests.

As recently emphasised by the new Forest Practices Code of British Columbia, silvicultural systems for ESSF forests need to be site-specific, reflecting the complex, sensitive nature of these ecosystems and their unique resource values.

In the mid to late 1980's, researchers in the Prince George Forest Region anticipated the changing needs of forest practices. The Lucille Mountain Project was established in 1991 as a multidisciplinary research project, involving detailed scientific comparisons of different silvicultural systems in the ESSF zone. This group of forest scientists are focusing their attention in the areas of subalpine forest regeneration, microclimate, tree and stand growth, mortality, plant succession and caribou habitat.

In conjunction with similar trials in ESSF forests in other parts of BC, the Lucille Mountain Project will increase the biological understanding of these forests. It will help BC foresters and the public make informed choices about future forest management practices and assist managers in implementing the new Forest Practices Code.

Overall Project Objectives

The overall objective of the project is to compare the biological implications of various harvesting methods and silvicultural systems in the ESSFmm (moist, mild) biogeoclimatic subzone. Because of its complexity, this project is divided into many different sub-projects. This report will deal with early results of only five of those sub-projects: monitoring and describing the microclimate and light environment, planted and advance regeneration, seed supply and natural regeneration and arboreal forage lichen availability for mountain caribou.

A number of other projects are underway or are scheduled to begin in the near future. Those projects are not discussed in this report as they are too preliminary to provide useful information. Those results will be reported as they become available.

Dr. Bob Sagar downloads winter data from a computerized climate station in the Lucille Mountain clearcut

Site Description

The research site is located 8 km south-west of McBride on a mesic site in the Moist, Mild Engelmann Spruce-Subalpine Fir subzone (ESSFmm). It is situated on a north-west slope at an elevational range of 1375-1600 metres. The slope ranges from 20-40%. The soils are silt loam to sandy loam with 2 to 3 metres of glacial till over bedrock, resulting in a high fragment content.

The stands within and around the study site are fairly typical of unlogged mature old growth Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) sites in the region. The forest is 250 to 300 years old. The uncut stands contain a high proportion of snags. Regeneration of spruce and fir are primarily confined to favourable microsites such as rotting wood. The shrub layer is dominated by shrubs such as white flowered Rhododendron (*Rhododendron albiflorum*), false azalea (*Menziesii ferruginea*) and huckleberry (*Vaccinium spp*). The herb layer is typified by trailing raspberry (*Rubus pedatus*) and twisted-stalk (*Streptopus roseus*).

Treatments Applied

Treatments were designed to produce a spectrum of different cutting patterns and stand structures from single tree selection to clearcutting in this ESSF subzone. A total of five silvicultural systems were applied on the site (figure 1). The group selection, irregular shelterwood and single tree selection sites were replicated five times. The small patch cuts were replicated four times for each of the three regeneration treatments. The clearcut consists of one 32 hectare opening. A 40 metre uncut buffer strip was maintained between the clearcut and the selection treatments.

Even-aged Stand Structures

Clearcut

The goal of the clearcut prescription was the complete removal of the mature stand. The regeneration established after harvesting is even-aged, with fairly uniform species composition and spacing relative to the original old-growth stand. The primary regeneration method was planting of Engelmann spruce throughout, and mixed planting of subalpine fir and spruce on the research plots. The stand structure goal for the clearcut system is an even-aged plantation of Engelmann spruce with incidental natural and advance regeneration.

The 32 hectare clearcut block was hand-felled and summer-logged in 1991. Rubber-tired skidders were used to skid the felled tree-length wood to 3 landings. Research areas in the clearcut were summer-planted in July 1992, with rows of hot-lifted 2+1 BR415 subalpine fir and 2+0 PSB 315 Engelmann spruce.

Small Patch Cut

The overall goal of the small patch cut prescription was to create a small-group harvest pattern that met visual quality and biodiversity goals while facilitating timber harvesting and the establishment of both planted and natural regeneration in harvested areas. The mature forest surrounding these 0.2 hectare patch cuts may provide seed and shelter through shading and reduced wind speeds for the regenerating area.

Approximately 50% of the area of the old stand was removed in fourteen 0.2 hectare small patch cuts (45 m x 45 m) in a 'checkerboard' pattern. The patch cuts are slightly less than 2 mature tree lengths wide. Of the fourteen patch cuts, eight were harvested on bare ground or light snow, while six were winter-harvested on a 1 metre compressible snowpack in February 1992. These winter blocks were harvested using D4 hi-drive tracked skidders. All the winter logged patch cuts were sanitation spaced in September of 1992.

Regeneration within individual patch cuts will be generally even-aged. Including the mature retention patches, the structure of the resulting stand is a mosaic of two age-classes. Within the patch cuts, three different even-aged regeneration strategies are being compared, including:

- natural regeneration from seed on summer harvested patch cuts;
- planted regeneration of spruce and fir on summer harvested patch cuts;
- preservation of existing advance regeneration on patch cuts winter-logged on deep snow packs.

Uneven-aged Stand Structures

The overall goals of the group selection, irregular shelterwood, and single-tree selection prescriptions were to create a dispersed harvest pattern, and create or maintain two-aged to uneven-aged structures that:

- maintain the structural complexity of the pre-harvest stand;
- provide shelter for planted, advance, and/or new natural regeneration;
- provide seed for natural regeneration;
- mitigate visual impacts of harvesting, and;
- provide wildlife habitat.

Each of these three treatments was replicated in a randomized complete block design in five randomly-selected one-hectare treatment units within a 15 hectare area adjacent to the clearcut block. Approximately 50% of the pre-harvest volume and basal area were removed in the single-tree selection and irregular shelterwood treatments. Volume removal in the group selection treatment was approximately 65%.

The general intent of all treatments was to achieve the desired stand structure and volume removal while retaining better-than-average-quality trees and maintaining pre-harvest species composition. Individual trees were "marked-to-leave" with blue paint.

All these areas were partially-cut in February 1992, on a 1.0 to 1.5 metre compressible snowpack. The trees were hand-felled and the timber was skidded tree-length to landings using two Caterpillar D4H Hi-drive crawler-tractors with 30 inch tracks. All snags were felled to comply with Workers Compensation Board regulations and the merchantable trees not marked to leave, were felled and skidded.

The sapling and pole tree layers in the group selection, irregular shelterwood, and single-tree selection treatment units were sanitation thinned in August of 1992, to fell residual stems or advance regeneration that had been excessively damaged during harvesting.

Group Selection

The goal of the group selection treatment was to maintain the clumpy, heterogeneous stand structure typical of many mature forests at higher elevations. Natural groups containing predominantly thrifty mature trees, poles and thrifty advance regeneration were marked for retention. Mean basal area removal was 66.5%. Approximately 450 seedlings per hectare of Se 1+0 PSB 415 stock were fill-planted in half of each group selection treatment units in early June, 1995. As a comparison, the other half of each treatment unit is to be naturally regenerated.

Irregular Shelterwood

The stand structure goals for the irregular shelterwood treatment were:

- to create a two-aged to multi-aged residual stand structure by retaining relatively uniform distribution of overstory co-dominant and dominant trees, and
- to protect the understory of advance and planted regeneration.

Past studies found that larger pole-size advance regeneration usually sustained heavy damage during partial-cut logging operations. These stems are more numerous and harder to avoid than the mature stems. They are more easily damaged than small flexible advance regeneration which are protected by deep compressible snowpacks.

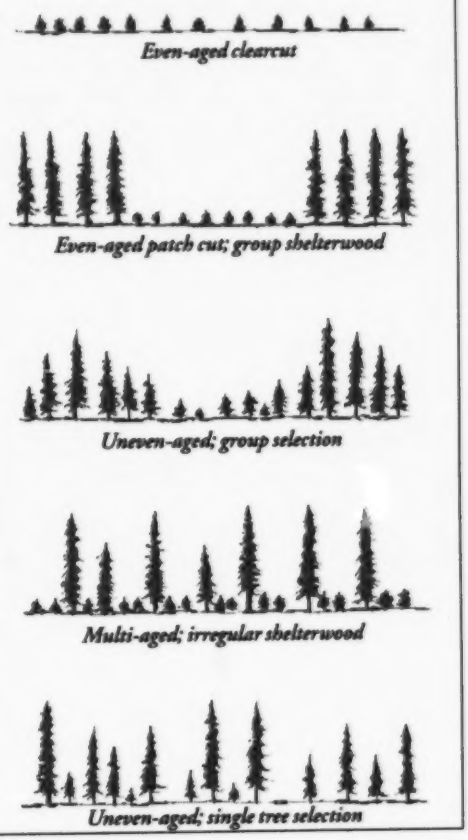
In this treatment, many larger overstory trees, but relatively few intermediate pole-sized trees were marked for retention. Heavy stem removal in the intermediate pole layers was prescribed to aid the establishment of a planted spruce regeneration layer under the residual overstory. If successful, this underplanting will eventually increase the spruce composition in the younger age classes.

Actual mean basal area removal was 50.1%, while actual mean volume removal was 47%. The irregular shelterwood treatment units were fill-planted with 450 seedlings per hectare of 1+0 Se PSB 415 stock in early June 1995. The research plots established in 1992 had higher density.

Single-tree Selection

This treatment represents the most traditional goals for a single-tree selection system. Individual trees of all diameter classes were marked for retention, with an approximate harvest removal of 50% across all diameter classes. Actual mean basal area removal was 45%, while actual mean volume removal was 44%. The single-tree selection treatment units are regenerated with natural and advance regeneration only. The utility of sanitation thinning of the understory

FIGURE 1. Different silviculture systems



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regeneration is being examined.

Microclimate

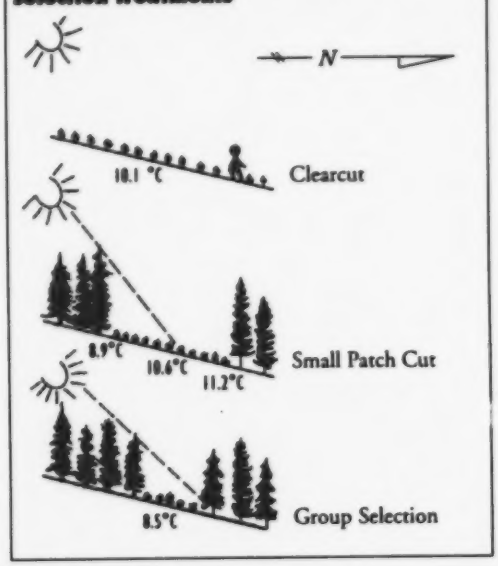
Objective

To monitor the microclimate in a range of forest opening sizes in the clearcut (32 hectares), small patch cut (0.2 hectares) and group selection (<0.04 hectares).

Methods

Microclimate monitoring stations were installed in the clearcut, group selection and small patch cut locations. Air temperature and relative humidity at 1.5 metres above the ground were measured at each site. Rainfall and solar radiation were recorded in the clearcut only. In addition to these basic variables, near ground air temperature at 5 and 30 centimetres above the surface and soil temperature at 10 centimetres below the surface, were measured to characterize the microclimate of various silvicultural systems.

FIGURE 2. Four year mean growing-season soil temperatures (10 cm depth) in the clearcut, small patch cut and group selection treatments



Site Climatic Conditions - 1992 to 1995

Table 1 summarizes the climatic conditions recorded at the clearcut site during the four growing seasons. The mean 1.5 metre air temperatures are not significantly different between the three treatments. Typical midsummer maximums were 20-25°C. However, it was common for temperatures to be in the 10-15 °C range during cloudy periods. Summer minimums were typically in the 5-10°C range. There was only one light growing season frost between June 20 and August 15 during the four years of monitoring. It is interesting to note that despite the lack of rainfall in 1992, vapour pressure deficits were probably not high enough to have a limiting effect on photosynthesis and seedling growth.

With only four years of data at these sites, it is not possible to state what the climatic normals are. However, the four seasons can be characterized as follows. The 1992 growing season was cool and very dry. The 1993 and 1995 growing seasons were cool and moist while the 1994 season was warm and moist.

TABLE 1. Summary of growing season climate conditions at lucille mountain (June 20 - Sept. 15; clearcut site)

	Clear Cut Site				*Growing Degree Days*				
	Mean Air Temp.(°C) at 1.5 m above ground	*Total Rainfall (mm)*	*Growing Season Frosts (June 20 - Aug 15)*	*Date of First Frost Ta (-0.5°)*	GDD (mean air temp > 5° C)				
					June	*July*	*Aug.*	*Sept*	*Total*
1992[1]	10.6	9	1	21 Aug	43	245	213	5	506
1993	10.6	188	0	12 Sept	42	160	208	87	497
1994	12.6	170	0	02 Oct	80	274	252	59	665
1995	10.8	264	0	18 Sept	88	192	103	130	513

[1] Data collection began on 27 June

Seedling Microclimate of Silvicultural Systems

Air and soil temperatures were measured both in the open and in groups of residual trees in the group selection system. In the small patch cut, these measurements were taken at the centre, north and south edges of the patch cut.

If it is assumed that the soil properties are consistent over all measurement positions, then the differences in soil temperature between positions are due to differences in the amount of solar radiation received at each position.

The mean 10 centimetre soil temperatures averaged over the 1992-95 seasons are shown for three of the silvicultural systems and measurement locations within them in Figure 2. The mean soil temperature for the centre of the opening at the group selection station are 1.6 to 2.1°C lower than those in the clearcut or centre of the small patch cut. This is probably due to increased shading from the residual trees in the much smaller openings of the group selection compared to the clearcut or small patch cut.

In the small patch cut, the mean soil temperatures at the south edge measurement locations in figure 2, are significantly cooler (1.7 to 2.3°C) than those of the north edge and centre locations. The south edge locations are shaded for most of the day. There was very little difference between the uncut group and opening of the group selection on a seasonal basis.

The near ground air temperature measurements did not identify conclusive differences between the treatments. This may be partly due to measurement uncertainties associated with the sensor. However, it is well known that seedlings under or near taller vegetation may experience higher needle and bud temperatures than those in an exposed location. The extent to which this is true will depend of the proximity of the seedling to the overtopping vegetation and how much of the sky, as 'seen' by the seedling, is obscured by the taller vegetation.

The lack of growing season frosts was somewhat surprising for a high elevation site such as Lucille Mountain. This lack of frost incidence is likely due to the location of this study on sloping terrain (20-30%), which allows cold air to drain off the site. It is important to note that these results may not hold

true for all ESSF sites, particularly those on terrain prone to cold air ponding.

Light Environment

Objective

To compare the light environment in various partial cut silvicultural systems and in an uncut stand.

Methods

In order to assess the light environment of the different partial-cut harvesting systems, light measurements were measured at random locations along a transect running through the single tree selection system, group selection, and irregular shelterwood treatment unit. Measurements were also taken in the adjacent undisturbed mature forest.

Photosynthetically active radiation (PAR) measurements above and below the shrub canopy were recorded at each sample location, using a hand-held Decagon integrating radiometer.

Results

All partial cutting treatments substantially increased the amount of light available both above and below the shrub canopy, compared to the uncut forest. (Figure 3). The light environment as estimated by PAR, was most improved for the irregular shelterwood and least for the single tree selection system. The single tree selection treatment likely has the lowest PAR levels because more stems were left in the sapling to pole size classes, thereby increasing the amount of shading by the tree canopy.

The average light levels beneath the shrub canopy in the uncut control were about 3% of full sunlight, on the lower end of the compensation range for white spruce and subalpine fir growing in understory environments. (see insert box) Growth potential is extremely limited under these conditions. In contrast, the average light measurements beneath the shrub layer in the partially cut stands was about 17% of full sunlight.

Overall, these results suggest that the light regime created by a 50% partial cut is sufficient for regeneration and adequate growth of spruce and subalpine fir. Regeneration growth will likely be less than optimal during seedling establishment. However, once the regeneration layer grows above the shrub layer, light levels and growth rates will likely increase.

Planted and Advance Regeneration

Objective

To compare short and long-term survival, growth, and crown morphology of planted and advanced Engelmann

How Much Light does Spruce Need ?

Light is a critical limiting factor in photosynthesis. Partial-cut or mixed wood silvicultural systems can reduce light levels for understory conifer seedlings. Achieving forest regeneration goals under these conditions requires an understanding of critical light levels for the growth and survival of specific tree species.

White and Engelmann spruce are planted throughout the north-central interior. They have similar ecological requirements, including moderate shade-tolerance. Coates et al (1994) reviewed the literature on the light relations of spruce. The following is a brief synopsis of this review.

Light measurements, recorded as photosynthetically active radiation (PAR), represent the range of light wavelengths that plants use to photosynthesize. PAR generally corresponds to the visible light spectrum. The PAR measurement for full sunlight on a totally clear summer day between 12:00 and 14:00 hours is approximately 2,000 ○mol/m²/s. By comparison, a bright cloudy day may be in the range of 1,000 to 1,500 and a dark rainy day, approximately 600○mol/m²/s.

Two key concepts for understanding the effect of light intensity on plant photosynthesis are the light compensation point, and the light saturation point.

Light Compensation Point *is the light intensity at which net photosynthesis is zero: the plant's energy absorption through photosynthesis is matched by the energy costs of respiration.*

The light compensation point is approximately 2 to 6 % of full sunlight for white and Engelmann spruce

Light Saturation Point *is the light intensity at which photosynthesis is maximized and further increases do not produce additional photosynthesis.*

The light saturation point is 25 to 40% of full sunlight for white and Engelmann spruce

However, light effects on photosynthesis only do not appear to tell the full story. Nutrient supply, frost exposure and soil temperature are just a few other environmental factors that are modified by overhead cover and can combine with a complex of factors to affect tree growth. Also, while spruce can survive very low light levels for a few years, vigorous long-term survival and growth requires higher light levels.

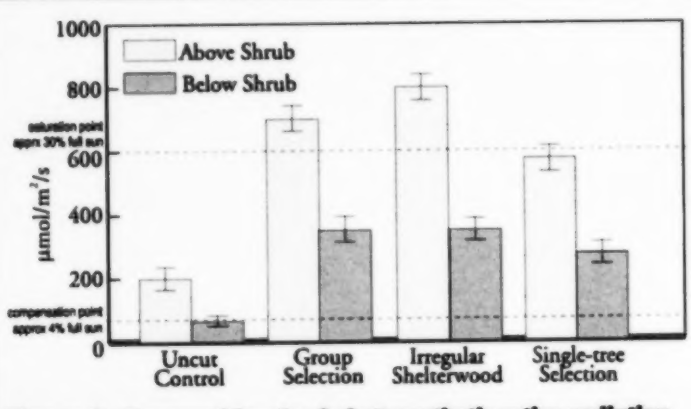


Figure 3. Measured levels of photosynthetic active radiation (PAR) available to seedlings above and below the shrub layer in various partial cut systems at the Lucille Mountain site.

spruce and subalpine fir in clearcut, small patch cut, and irregular shelterwood silviculture systems in the ESSF.

Methods

Engelmann spruce and subalpine fir seedlings were planted in five plots in each of the clearcut, small patch cut and irregular shelterwood sites. The plots were planted with hot-lifted PSB 2+0 415 spruce and PBR 2+1 415 subalpine fir in the summer of 1992. Survival assessments were done in the fall of 1992 and fifteen trees of each species were measured after each growing season starting in the fall of 1993. Height, leader growth, crown volume vigour and crown morphology were recorded for each seedling and the trees were numbered and tagged.

There are five advance regeneration plots per treatment in each of the clearcut and irregular shelterwood treatments and four in the small patch cut. Sample trees were located randomly on a 4 metre square grid for a maximum 25 spruce and 25 fir identified in each plot. The height, diameter, leader growth, crown diameter, rooting substrate and vigour were recorded for each sample tree and the trees were tagged for relocation. 552 spruce and subalpine fir advance regeneration up to 1.3 metres in height were identified and tagged prior to harvest in 1990. They were located and assessed for survival and damage after harvest and again in following years for height and crown volume measurements

Future remeasurements for the planted and advance regeneration are scheduled for 5, 7, 10, 15 and 20 years after harvest.

FIGURE 4. Three-year Planted Regeneration Survival by Species and Silvicultural System

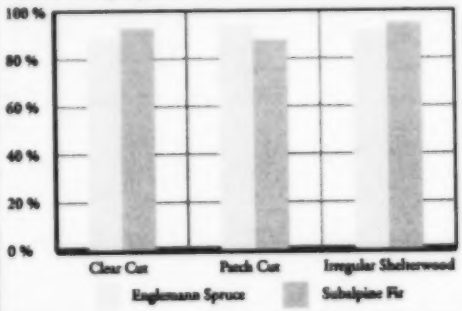
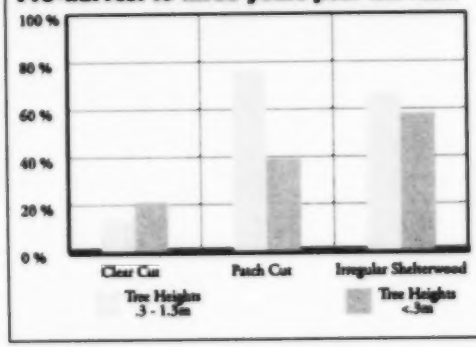


FIGURE 5. Advance Regeneration Survival by harvest treatment and size class: Pre-harvest to three years post-harvest.



Planted Regeneration Survival

The planted trees experienced a late August frost just 4 weeks after being planted in 1992. A substantial number of trees in the clearcut and small patch cut exhibited signs of apparent frost damage including leader or lateral shoot die-back. Seedlings in the irregular shelterwood units had little or no such damage at that time. However, during the first three years, the average survival rate of both Engelmann spruce and subalpine fir seedlings was approximately 88 to 95% in all treatments, with no significant differences between species or treatments (figure 4).

In all the planted treatments, initial growth of the spruce seedlings was slow, possibly due to planting "shock" and some frost damage. However, trees in all treatments are recovering. The subalpine fir seedlings showed little growth in the first growing season but have recovered to varying degrees in all treatments. Up to the first three years after planting, average seedling crown volume was lowest in the clearcut for both subalpine fir and spruce. This reduced crown volume may be due to frost damage to seedlings in the clearcut.

The most recent growth data for the planted seedlings suggests that both the planted spruce and subalpine fir in the clearcut treatment are starting to overtake those in the small patch cut and irregular shelterwood in terms of leader growth and crown volume, after an initially slower start (Jull, unpublished data). However, this trend is very preliminary at present and a full analysis will be presented in future research reports.

Advance Regeneration Survival

For analysis, two tree size classes - trees less than 0.3 metres, and trees greater than 0.3 metres height but less than 1.3 metres height were defined. Survival rates reported here are based on trees surviving to three years after harvest, incorporating both mortality at harvest, and mortality in the years following harvest (figure 5).

As expected, advance regeneration survival was lowest in the summer-logged clearcut for both the 0.3 metre and 0.3 to 1.3 metre size classes.

The low survival of both <0.3 metre and 0.3 to 1.3 metre advance regeneration size classes in the summer logged clearcut treatment relative to the winter logged small patch cut and irregular shelterwood is a strong indicator that winter logging on snow pack significantly reduces mortality of small regeneration during falling and skidding activities.

Somewhat surprisingly, the small seedling size classes (< 0.3 metres) had consistently lower survival than the sapling (0.3 to 1.3 metres) size classes in the winter patch cut and irregular shelterwood units, despite theoretically better protection of smaller trees by snowpacks from physical damage during logging and skidding. This apparent contradiction may be due to the impact of fine logging slash (on the snow surface) smothering small seedlings after snowmelt. This was widely observed in the first spring after harvest.

Seed Supply and Natural Regeneration

Objective

To determine the feasibility and reliability of natural regeneration for subalpine fir and Engelmann spruce in the ESSF by monitoring cone crop periodicity, seed vi-

ability and dispersal, seedbed requirements and subsequent germination over time in the clearcut, small patch cut and single tree selection systems.

Methods

Natural regeneration was monitored within the single-tree selection, small patch cut, and clearcut. Cone crops were rated annually starting in 1992 and cones were collected to determine the number of filled seeds per cone. Seed fall was monitored in five replicated plots in the single-tree selection and clearcut and four plots in the small patch cut. Seeds were collected in seed traps for assessment of the number and viability of conifer seeds. In 1993, seedbeds were prepared and direct seeded in a split-plot design to produce 4 treatments: screefed and not screefed, and seeded and not seeded. Since August of 1994, the total number of spruce and fir germinants have been counted annually in each seedbed treatment.

Results

Harvesting treatments appear to have had no effect on the abundance of cones nor the frequency of heavy cone crops up to three years after harvest. While 1993 was a heavy cone crop year, 1994 was a very light year.

Engelmann spruce produced more filled seeds per cone than did subalpine fir on average across all treatments with 57 seeds/cone and 32 seeds/cone, respectively. Within all harvesting treatments, the incidence of insects and disease was high in spruce cones and infrequent in subalpine fir cones.

The seed trap data shows that seed fall was less in the clearcut compared to the small patch cut and single-tree selection in both a heavy cone crop year (1993) and low cone crop year (1994). The small patch cut and single tree selection systems had approximately 100 times more total subalpine fir seed and 15 times more spruce seed than the clearcut in 1993. The percentage of filled seeds per species and silviculture system was similar, ranging from 32 to 44 percent of total seed fall. In contrast, seed fall was much lower and more variable in 1994 and there were no filled seed in any of the seeds collected that year.

It is evident from figure 6 that a disturbed forest floor, either by screefing or logging disturbance, dramatically improves the germination of both spruce and subalpine fir seeds. Direct seeding of germination plots with undisturbed forest floor only slightly improved the total number of germinants compared to unseeded plots. This difference between seeded and unseeded was much greater on the disturbed plots. These results are from 1993 with a relatively heavy cone crop and high seed production in the surrounding stands. The difference between seeded and unseeded plots may have been larger if the cone crop had been lighter. The clearcut suffers from lack of seed supply as illustrated by the small numbers of germinants when additional seed was not applied.

Arboreal Forage Lichens

The study area is in the range of habitat for mountain caribou *(Rangifer tarandus caribou)* which depend almost exclusively on arboreal lichens *(Bryoria spp.* and *Alectoria sarmentosa)* for winter forage for several months of the year. The mountain caribou are a blue listed species by the BC Ministry of the Environment. This means that they are sensitive or vulnerable because of low or declining populations.

Objectives

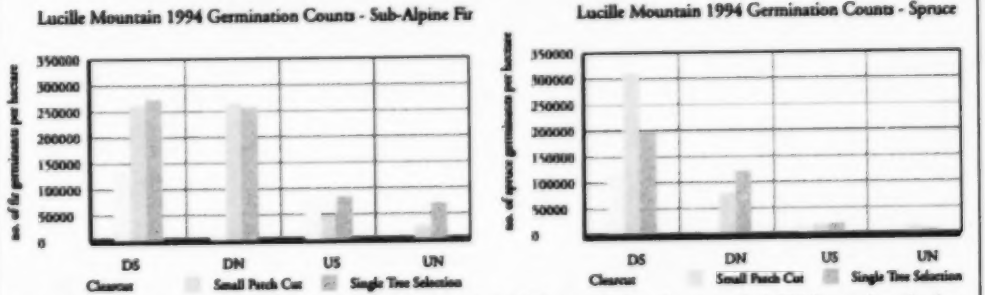
1. To compare the abundance of available forage lichens for mountain caribou after harvesting in the irregular shelterwood and single tree selection system in relation to a mature unharvested stand.

2. To measure the growth rates of *Bryoria* spp. and *Alectoria sarmentosa* in the lower canopy of the residual trees in the irregular shelterwood, group selection and mature forest.

Methods

Prior to harvest, lichen abundance was estimated using the clump method (Stevenson and Enns, 1993) in 30 plots in each of the irregular shelterwood, single tree selection system and mature forest control. A 5 gram clump of lichen was used as a standard unit and the number of clumps on each sample tree below 4.25 metres was estimated. In 1992, the clump method and a new photo-based method (Armleder et al. 1992) were used to assess lichen

FIGURE 6. Number of Sub-Alpine Fir and Engelmann Spruce germinants per hectare within three silvicultural systems



Germination plot treatments were: screefed and seeded (DS), screefed and not seeded (DN), undisturbed and seeded (US), or undisturbed and not seeded (UN).

abundance in all of the plots after harvest.

Growth rates of arboreal lichens were measured by repeatedly weighing lichen thalli that were attached to an artificial substrate and grown in the field. The lichens were attached to glass tubes which are fitted into small mesh enclosures and suspended from the lower branches of trees. In spring and fall the lichens were brought into the laboratory, allowed to stabilize to the laboratory humidity, reweighed and returned to the field. Lichen weights were adjusted to a standard humidity level using formulae developed by Stephen Walker of the Cariboo Forest Region.

Air temperature and relative humidity are continuing to be measured using probes attached to branches 3 to 4 meters above the ground on sample trees.

Results

Selection harvesting in the irregular shelterwood and single tree selection system reduced the amount of available lichen not only through removal of marked trees, but also through clearing for roads and landings, felling of snags, and other losses (figure 7).

At some other sites, there has been considerable loss of lichens from the residual stand due to disturbance during logging, subsequent wind-scouring of the newly exposed trees and windthrow. At Lucille Mountain only 3% of the lichen losses in the summer after harvest, were attributable to these sources.

The growth rate data available so far indicate that the selection harvesting at Lucille Mountain has had a mildly negative impact on the growth rates of *Alectoria sarmentosa* but not necessarily on the growth rates of *Bryoria* spp. The overall impact of the treatment on *Bryoria* spp. is not clear, as it has been inconsistent among seasons. The fastest lichen growth rates were observed in the summer of 1994, which was relatively warm and moist in comparison to 1992 and 1993.

Since the inception of the Lucille Mountain project, preliminary recommendations for the application of silvicultural systems in caribou habitat have been developed (Stevenson et al. 1994). They call for a maximum volume removal of 30%, which is much lower than the volume removal at Lucille Mountain. Where lichens available on dead trees are a large component of the overall lichen supply, as they were at Lucille, managers may consider harvesting methods that allow for snag retention without compromising the safety of workers.

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Future Work

The Lucille Mountain ESSF Project is designed as a long-term study to last 20 years or more.

Following five-year treatment assessments in the 1996 field season, research reports on results to date will be prepared and published. Such reports will provide more extensive and in-depth analyses of results than are possible in the research note format.

Future research reports will also be issued after 7, 10, 15 and 20 year post-harvest milestones.

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FIGURE 7. Impact of logging on available lichen, Lucille Mountain